Comparative study of different adsorbent materials in a charcoal canister

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By

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UNDER THE GUIDANCE OF

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CANDIDATE'S DECLARATION

I hereby declare that the work, which is being presented in the dissertation entitled "**Comparative study of different adsorbent materials in a charcoal canister**" in the fulfilment of the requirements of the award of the degree of **Bachelor of Technology** in **Mechanical Engineering,** submitted in the Department of Mechanical Engineering, National Institute of Technology, Rourkela, Orissa, is an authentic record of my own work carried out during the period of July 2012 to April 2013 under the supervision of **Dr. S.Murugan**, Associate Professor, Department of Mechanical Engineering, National Institute of Technology, Rourkela, Orissa. I have not submitted the matter, embodied in this dissertation for the award of any other degree.

Date: 8th May 2013

(PROTSAHAN PRADHAN)

Place: Rourkela

CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief.

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PROTSAHAN PRADHAN

ABSTRACT

Evaporative emissions account for 15-20% of total hydrocarbon emission from a gasoline engine. Evaporative emissions from the fuel tank and the carburettor are inevitable from gasoline or gasoline like fuel operating vehicle because of their highly evaporative nature. Evaporative emission control technique are introduced in S.I. engine vehicles in order to reduce the hydrocarbon emission. Charcoal canister is a fuel evaporative emission control device that is fitted between the space between the fuel tank, carburettor and the intake manifold. The design of the charcoal canister plays an important role for the maximum reduction of hydrocarbon. The present work aims to design a charcoal canister consisting of inlet tubes for fuel vapour from the fuel tank and the carburettor for introducing vapour into the charcoal canister and a bed of adsorbent, EPDM(ethylene-propylene-diene monomer) foam filter to trap liquid gasoline and heavy hydrocarbons that may spill from the fuel tank and the float of the carburettor. A vapour purge tube in the fluid communication with the bed of activated charcoal for purging fuel from the bed .A exhaust gas recirculation (EGR) system is used to enhance the desorption of the vapour fuels due to higher temperature and evaluate the performance of different adsorbent materials(activated carbon powder, charred wood powder,) by experimentation with help of a fabricated charcoal canister.

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CHAPTER I

1.1 Introduction

Emissions from motor vehicles includes the by-products that comes out from the exhaust systems and other hydrocarbon emissions such as petrol vapour, gasoline by evaporation. These emissions are the major cause of the air pollution and are major cause for smog creation in the cities.

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1.2. The main vehicle emissions are:

1.2.1 NO_x (nitrogen oxides):

The nitrogen oxides usually reacts with ammonia, water vapour and other compounds to form nitric acid vapour and related dangerous particles. These small particles can get into our lungs tissue and damage it badly and may result in premature death in extreme cases. Inhalation of these particles may result in emphysema and bronchitis like diseases.

1.2.2 Volatile organic compounds:

The nitrogen oxides react with volatile organic compounds in the presence of sunlight,ozone is formed which is the major cause of formation of smog. Vehicles are the second largest source of VOCs.

1.2.3 Ozone:

Though the ozone layer is quite beneficial in the upper layers of the atmosphere, ground level ozone creates damages in the respiratory system which causes coughing,chocking,and reduced capacity of the lungs. It also hampers the production of crops.

1.2.4 Carbon monoxide(CO):

Carbon monoxide is the most poisonous air pollutant and is fatal in high concentration. It is odourless,colorless and tasteless but has high toxicity. It gets attached with our haemoglobin to form carboxy-hemoglogin which lack the capacity of carryin oxygen and affects the delivery of oxygen to various tissues of the body.

1.2.5 Hazardous air pollutants (toxics):

Chronic exposure to benzene (C_6H_6),emitted from vehicle damages the bone marrow. It also causes excessive bleeding and depress the immune system,and an increased the chance of infection. It causes leukemia.

1.2.6 Particulate matter (PM_{10} and $PM_{2.5}$):

The effects of inhaling airborne particulate matter is widely studied in humans and animals and include diseases like asthma, lung cancer, cardiovascular issues, and premature death. Because of the size of the particles, they can penetrate the deepest part of the lungs, the alveoli and reduce the capacity of the lungs.

1.2.7 Carbon dioxide:

Vehicles are the major sources of carbon dioxide emission. As CO_2 is a green house gas it has a great effect in the climate changes occurring in various parts of the world. Global warming is the byproduct of the increasing CO_2 concentration in the environment.

TABLE 1.1 COMPOSITION OF EXHAUST GASES

POLLUTANT	% OF TOTALEXHAUST
NITROGEN	20.98
CARBON DI-OXIDE	14
WATER VAPOUR	11.92
CARBON MONOXIDE	1.32
TRACE ELEMENT	<0.5
OXIDES OF NITROGEN	<0.25
C_XH_Y(HYDOCARBONS)	<0.25

1.3.Evaporative emission:

The losses of petroleum can be divided into

1. quantitative (leakage or emission),
2. quantitative-qualitative (quantitative losses and a simultaneous deterioration of petroleum quality)
3. qualitative (deterioration of petrol quality without any physical bulk losses).

The reduction of petrol losses is one of the major ways saving the economy. If the stocks of petroleum are limited and its extraction requires increasing efforts,
it is natural to pay more attention to saving the readymade product.
Irrespective of losses, liquid hydrocarbons finally escape in the atmosphere and have a negative impact on the environment and human health in particular. The emissions of high concentration of hydrocarbons cause an increase in respiratory diseases, Functional changes in the central nervous system etc. Exposure to volatile organic compounds (VOC) can bring a variety of harmful health effects, including asthma, headaches and, in some cases, an increased risk of cancer.
The greatest share of all kinds of losses during transportation, storage and use falls to evaporation. Such losses are very typical of hydrocarbons which easily evaporate . The specific losses of hydrocarbons due to evaporation at refineries in the different parts of the world make up 1.1–1.5 kg per 1 tone of petroleum. In 1998, the emissions of hydrocarbons in the processes of petroleum production in the Russian Federation comprised 1168 thousand tones. Besides, plenty of petroleum is lost during usage and as a result of wrong conservation. According to some information, refuelling stations of the Russian Federation release into the atmosphere more than 140 thousand tons of hydrocarbon fumes a year, whereas refuelling stations in Germany give 145 thousand and England 120 thousand tons a year. Evaporative emissions account for 15-20% of total hydrocarbon emission from a gasoline engine. The two main sources of evaporative emissions are the fuel tank and the carburettor.

1.3.1 Fuel tank losses- As the temperature inside the engine rises, the fuel tank heats up, the air inside the fuel tank expands, part of which goes out through the tank vent tube or leaves through the vent of the cap in the tank. This air is mixed with gasoline vapours. As the temperature decreases, the tank cools. The air inside the tank contracts and there is more space inside the tank. Air enters the tank from the atmosphere and ventilates it. This process of ventilation is called breathing.

1.3.2 Carburettor losses- The operation of an engine depends on the level of gasoline in the float chamber inside the carburettor. The engine stops running when the gasoline has been completely utilized. Heat produced by the engine causes evaporation of some quantity of gasoline from the float chamber. The evaporation of gasoline constitutes the main reason for the loss of gasoline from the carburettor. Approximately, 10% of the total hydrocarbon emission of the engine into the atmosphere is through the carburettor.

1.4.Emission control:

The efficiency of the engine has been steadily improved by the improved engine design, more precise ignition timing and electronic ignition, precise fuel metering, and computerized engine management systems.

The advancement in the field of engine and vehicle technology continuously reduce the toxicity of exhaust leaving the engine, but these measures taken have generally been proved insufficient to meet the goals of emission control. Hence, methods and process to detoxify the exhaust are an essential part of emissions control system.

1.4.1 Air injection

It is one of the first-developed exhaust emission control systems is the secondary air injection system. This system was used to inject the air into the engine's exhaust ports to provide oxygen sothat the unburned and partially burned particles nad hydrocarbons in the exhaust would finish the burning process. It is now used in the catalytic converter's oxidation reaction, to reduce the emissions when the engines are started from cold. After a cold start, the engines need a rich fuel-air mixture, and the catalytic converter does not function properly operating temperature has been achieved. The air injected upstream of the converter supports combustion in the exhaust pipe, which enhances the speed of catalyst warm up and reduces amount of unburned hydrocarbon emitted from the tailpipe of the exhaust system.

1.4.2 Exhaust gas recirculation

It is also helpful in reducing the oxides of nitrogen and for engine knock control. By circulating controlled amount of exhaust gases into the intake manifold the combustion temperature is lowered, this in turn, reduces the amount of NO_x emission. Exhaust neither burns nor supports the combustion, but it dilutes the air/fuel charge to decrease the peak combustion chamber temperatures. This, in turn, reduces the formation of NO_xin the vehicle.

1.4.3 Catalytic converter

The catalytic converter is a device wich is placed in the exhaust pipe. It converts the hydrocarbons, carbon monoxide, and NO_x to lesser damaging gases by using a combination of platinum, palladium and rhodium as catalysts in the system.

There are two types of catalytic converter:

2 a two-way

3 a three-way converter.

1.5. Evaporative emission control:

The main objective of the automobile evaporative emission systems is to decrease or eliminate the exposure of vaporized hydrocarbons (HC) into the atmosphere. The major sources of the HC vapor emissions is the vehicle fuel system EVAP emission control systems appeared in the automobile sector when it was found out that HC vapours in the atmosphere contributed to the formation of smog. These vapours were found to lead to a variety of respiratory ailments under prolonged exposure. As the recognition of the problem became greater, the governments began to legislate appropriate standards for control of the automotive emissions.

Positive crankcase ventilation better know as the PCVs were the first step towards the evaporative emission control system in the automobile industry. The purpose of the PCV system was to catch the vapours from the crankcase and prevent them from going out into the atmosphere through the road draft tubes.

The gases from the combustion chamber escapes into the crankcase of the engine through the process called “blow-by”. Blow by occurs when the compressed fuel and air mixture leaks into the crankcase through the piston seals. These gases trapped in the crankcase slowly gets out through the vents into the atmosphere. Another major concern of presence of combustion gases in the crankcase is that they increase the Ph in the oil which accelerates the wear of the vital components like bearings and seals of the engine.

The PCV valve system regulates the return of the crankcase vapours to the engine’s intake manifold. These vapours then get mixed with the engine’s intake air and/or fuel/air mixture and re-enter into the combustion chamber for ignition. This ensures that all of the HC vapours are exposed to the combustion process, thus decreasing HC emissions from the crankcase to the atmosphere.

The main objective of EVAP system is to prevent the release of harmful VOCs into the atmosphere. The main concern is the unburnt fuel vapors from the exhaust of the engine. Hcs are released in the form of vapour and if the system carrying the fuel is not air tight then the vapors gets a chance to escape into the atmosphere. These HCs are the major cause of smogs.

There are four ways in which these petrol vapors are produced and allowed to escape.

1 **Diurnal evaporation:** It occurs during the daylight hours when the fuel is heated by an increase in ambient temperature. The rise in temperature increases vaporization.

2 **Running losses:**It is the result of heat in the engine compartment from the exhaust system and the operation of the engine, both of which cause fuel vaporization.

3 **Hot soak:** After an engine is turned off, the radiant heat will cause gasoline vaporization for an extended period.

4 **Refueling:** Fuel vapors are always present in the fuel tank. When liquid fuel is added to the tank, it displaces the vapors by venting them into the atmosphere.

Evaporative emission control system is designed to store and dispose of fuel vapours normally created in the fuel system, thereby, preventing its escape to the atmosphere. The EVAP system delivers those vapours to the intake manifold to be burned with normal air/fuel mixture. This fuel charge is added during periods of closed loop operation when additional enrichment can be managed by the closed loop fuel system. Improper operation of the EVAP system may cause rich drivability problems, as well as harm the working of the working of the engine.

EVAP is a fully closed system designed to maintain stable fuel tank pressures without allowing fuel vapours to escape to the atmosphere. Fuel vapour normally created in the fuel tank as a result of evaporation. It is then transferred to the EVAP system **charcoal canister** when tank vapour pressures become excessive. When operating conditions can tolerate additional enrichment, these fuel vapours are purged into the intake manifold and added to the incoming air fuel mixture.

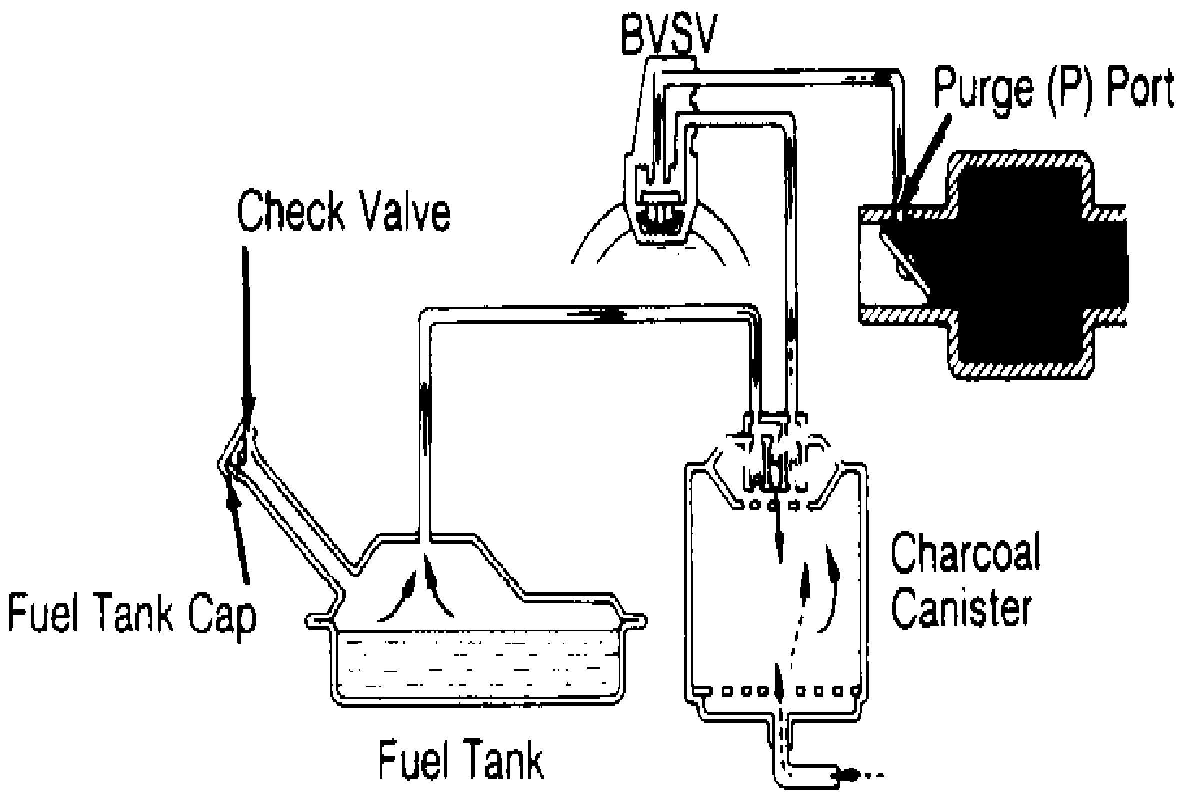


FIG. 1 EVAP SYSTEM

There are two basic types of evaporative emission control systems:

- **Non-ECM controlled EVAP systems** use solely mechanical control devices to collect and purge stored fuel vapours. Typically, these systems use a ported vacuum purge port and a Thermo Vacuum Valve (TVV) to prohibit cold engine operation.

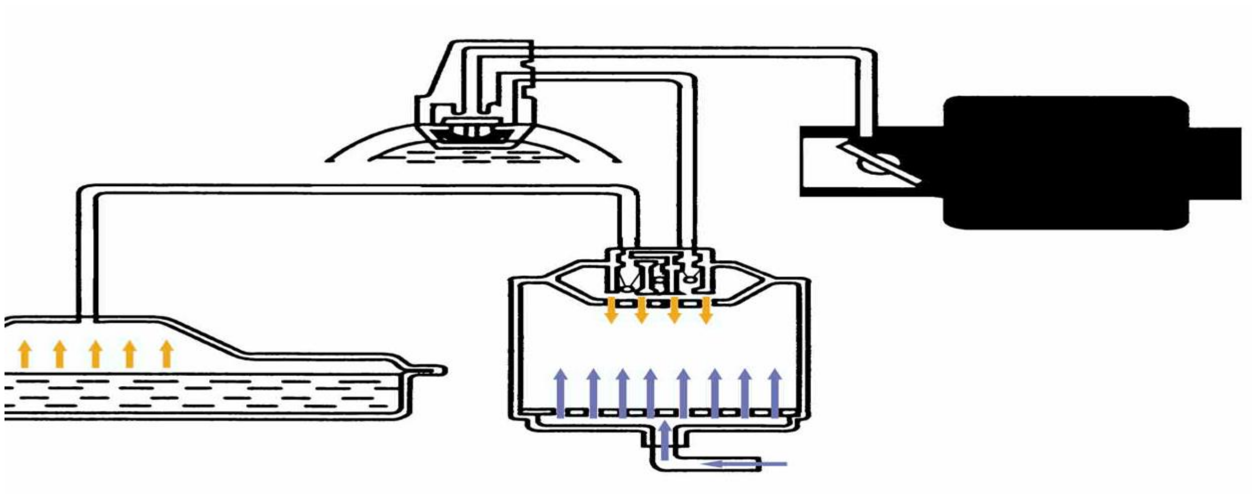


FIG. 2 **Non-ECM controlled EVAP systems**

- **ECM controlled EVAP systems** use a manifold vacuum purge source in conjunction with a duty cycled Vacuum Switching Valve (VSV). This type of EVAP system has the ability to provide more precise control of purge flow volume and inhibit operation. This is the only type on current models.

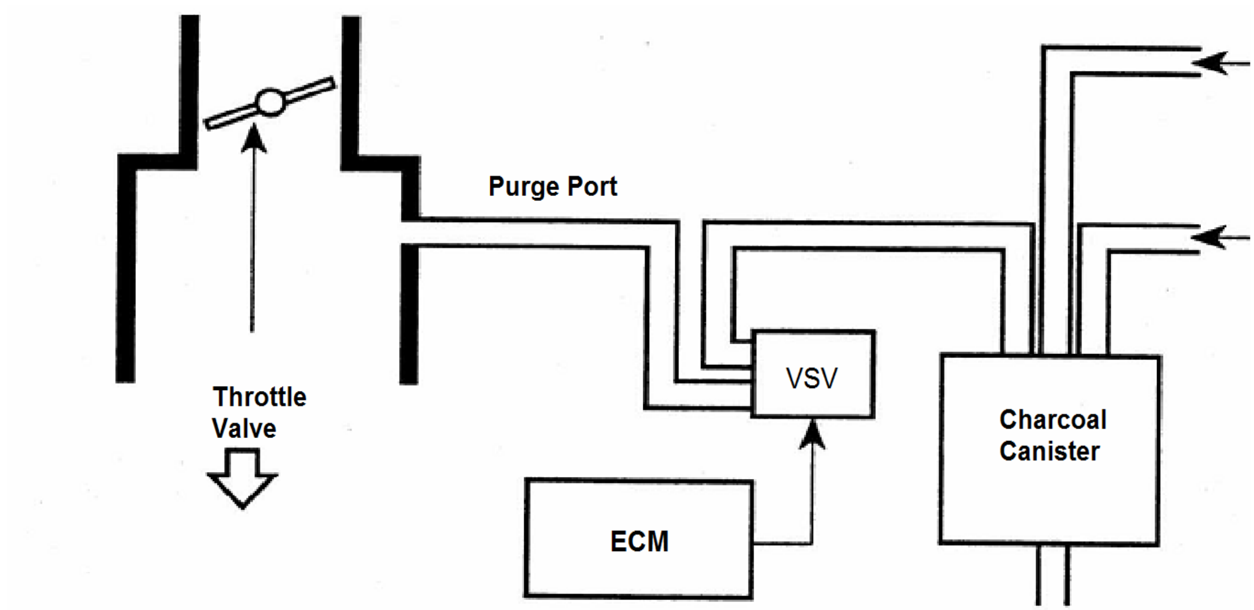


FIG. 3 **ECM controlled EVAP systems**

CHAPTER II

Literature Review:

2.1 Masatami Takimoto & Koichi Mizutani:

In order to prevent the evaporation fuel emission, an internal combustion engine has a charcoal canister arranged between the spaces in the fuel tank and in the float chamber, and the atmosphere. According to this device, the evaporative vapour is absorbed by the layer of charcoal in the canister. The thus absorbed fuel is desorbed by the purge air introduced into the purge air opening of the canister under the influence of vacuum pressure formed in the intake system when the throttle valve is opened, thereby the throttle valve is moved upstream of a fuel introducing port. The thus desorbed fuel is introduced into the engine via the fuel introducing port. Since this port is located slightly upstream of the throttle valve when it is in its idle position, the evaporative fuel cannot be introduced into the engine when the engine is operating under the idle condition.

2.2 Charles H. Covert & William E. Gifford:

A fuel vapour storage canister includes a vapour inlet for introducing vapour into the canister and a bed of adsorbent material in fluid communication with the inlet for adsorbing vapour within the canister. A vapour purge tube is in fluid communication with the bed purging fuel vapour from the bed. A thermoelectric cooler/heater selectively cools the inlet tube to promote condensation of vapours therein and selectively and alternatively heats the bed to promote purging of vapours from bed and heats the bed to promote purging of vapours from the bed and the remainder of the canister.

2.3 Ismat A & Abu Isa:

An evaporative fuel vapour control canister device can be built which has not only excellent fuel vapour absorption capability but also superior liquid fuel absorption capability. This is achieved by the incorporation of an elastomeric foam filter having unique liquid fuel absorption capability. A unique elastomeric foam material of EPDM has superior absorption efficiency for liquid gasoline and other high molecular weight hydrocarbon. Accidental spills of liquid gasoline and other high molecular weight hydrocarbons into the fuel vapour inlet are absorbed by the EPDM foam filters present between the fuel vapour inlet and the activated charcoal to prevent potential contamination of the latter.

2.4 Abhishankar Kumar

The adsorption characteristics of methane on granular activated carbon were measured over the temperature range of (293 to 323) K and at pressures up to 900 psi using a volumetric measurement system. The surface of activated carbon has been modified with copper oxides and sliver in order to improve the adsorption capacity of methane. The results indicate that the adsorption capacity can be marginally improved by doping small amount of metal oxides The adsorption data were fitted to different isotherm models and the result shows that DA are able to predict data correctly at all temperature.

CHAPTER III

3.1. Charcoal Canister

A charcoal canister is used to trap gasoline or petrol vapours. Fuel vapours from the float chamber of the carburettor and the fuel tank enters into the canister through a passage. Fuel vapours from the fuel tank enters through another passage into the canister. When the engine is not in running condition, the the fuel vapour flows into the canister through the inlet port. The petrol vapours are absorbed by the charcoal particles present in the canister. When the engine starts and run, air reaches the charcoal canister due to the suction provided by the engine in the intake manifold of the engine. This air carries away the hydrocarbons in the fuel vapours to the engine manifold and the fuel burns in the engine.

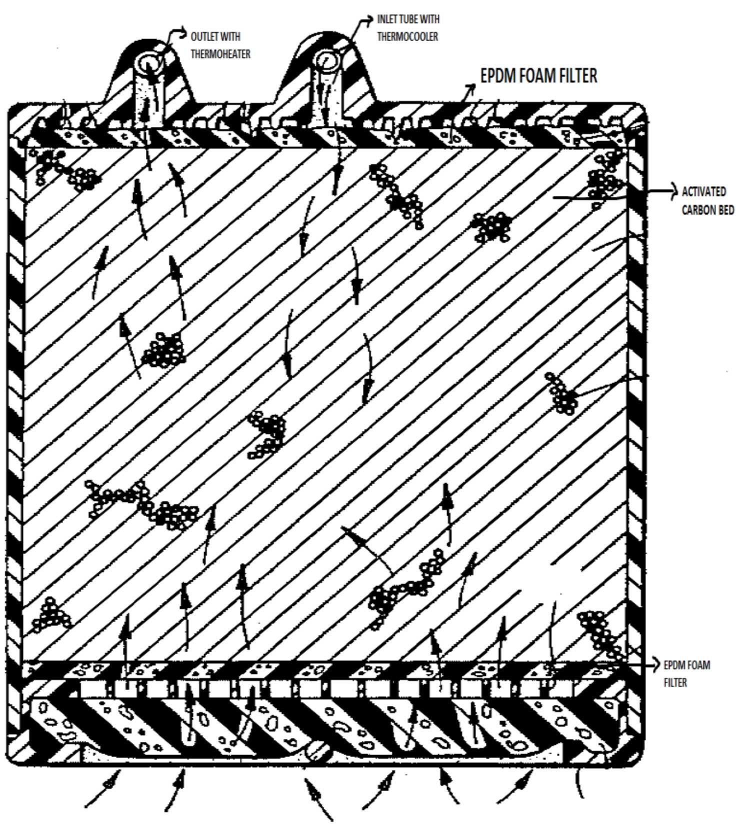


FIG. 4 CHARCOAL CANISTER

3.2. Main components of Charcoal Canister:

3.2.1 **Canister shell**: Aluminium tin alloy(low weight), perforated metal(for enabling suction during purging).

3.2.2 **Activated carbon:** It is material of very high surface area made up of millions of pores and is well known as "molecular sponge."

Properties:

- High surface area
- Very low density
- High adsorbing capacity(esprcially hydrocarbons.

3.2.3 **Charred wood:** I is the carbonaceous remaining of the wod after being burnt completely in presence of air. It has very high surface area and very low density. It can easily adsorb hydrocarbons on its surface. It is cheap, easily available and non poisonous in nature.

3.2.4 **EPDM(ethylene-propylene-diene monomer) foam filter:** It has superior adsorption efficiency for liquid gasoline and other high molecular weight hydrocarbons. This elastomeric foam material can adsorb up to five times its own weight of such liquids. When compared with activated charcoal material, the EPDM elastomeric foam adsorbs three times more liquid gasoline and other high molecular weight hydrocarbons than activated carbon.

3.2.5 **Exhaust Gas Recirculation System(EGR):** It is used for enhancing the desorption during purging. It is also helpful in reducing the oxides of nitrogen and for engine knock control. By circulating controlled amount of exhaust gases into the intake manifold through the charcoal canister, the combustion temperature is lowered, this in turn, reduces the amount of NO_x emission.

CHAPTER IV

Methods and materials

4.1. Design:

The design is made so that there is efficient flow of fuel vapours into the charcoal canister. The adsorption rate of the vapour by the charcoal canister should cope up with the rate of evaporation of fuel vapour from the fuel tank and the carburettor. The purging of vapour during the activation of the VSV valve should be smooth and efficient so as to control the air fuel mixture preventing too lean or too rich mixture into the intake manifold during the purging action.

4.1.1 Design details:

- One inlet at the bottom for controlled exhaust gas recycling.
- One inlet at the top for fuel vapours from tank.
- One outlet at the top for purging of vapours.
- EPDM foam filter on the top and bottom part of the cylinder.
- Adsorbent material, packed in the cylinder.
- Bottom part is perforated for entry of fresh air during purging.

ISOMETRIC VIEW **FRONT VIEW**

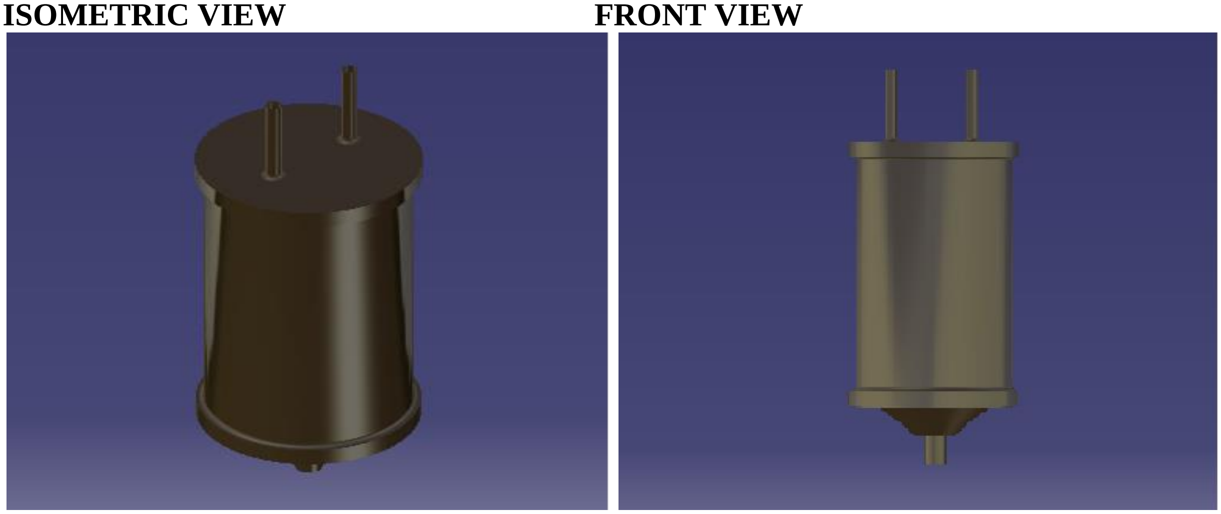
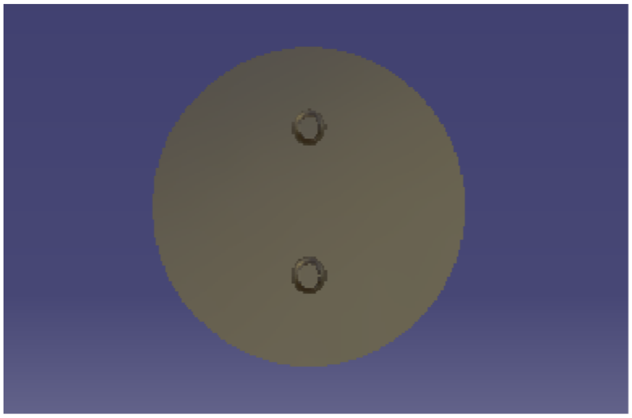


FIG.5

TOP VIEW **ANOTHER VIEW**



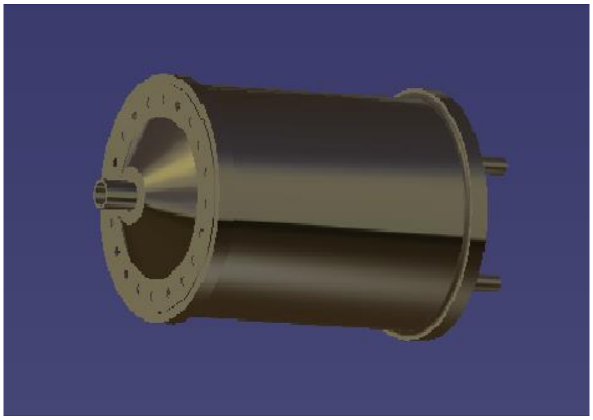


FIG.6

4.2. Fabrication of the canister:

4.2.1 Material and machines used:

1. Aluminium tin alloy air tight can
2. GI sheet
3. Hose barbs
4. Solder rod, solder wire
5. Nuts and bolts
6. Drill machine
7. Punch
8. EPDM foam or any foam type material.

4.2.2 Fabrication Procedure:

1. The aluminium tin alloy can base is drilled with small holes to convert it into a perforated base.
2. The GI sheet is given the designed shape with the help of bending machine, drilling machine and cutter.
3. Aluminium tin alloy can is welded with the gi sheet designed at the bottom for EGR by soldering.
4. Two holes are made on the top of the can which act as inlet and outlet ports.
5. Hose barbs are fitted through the holes.
6. EPDM foam filter fitted at the bottom and top of the can to prevent spilling of powder and adsorption of heavy drops of fuel spilled from tank.

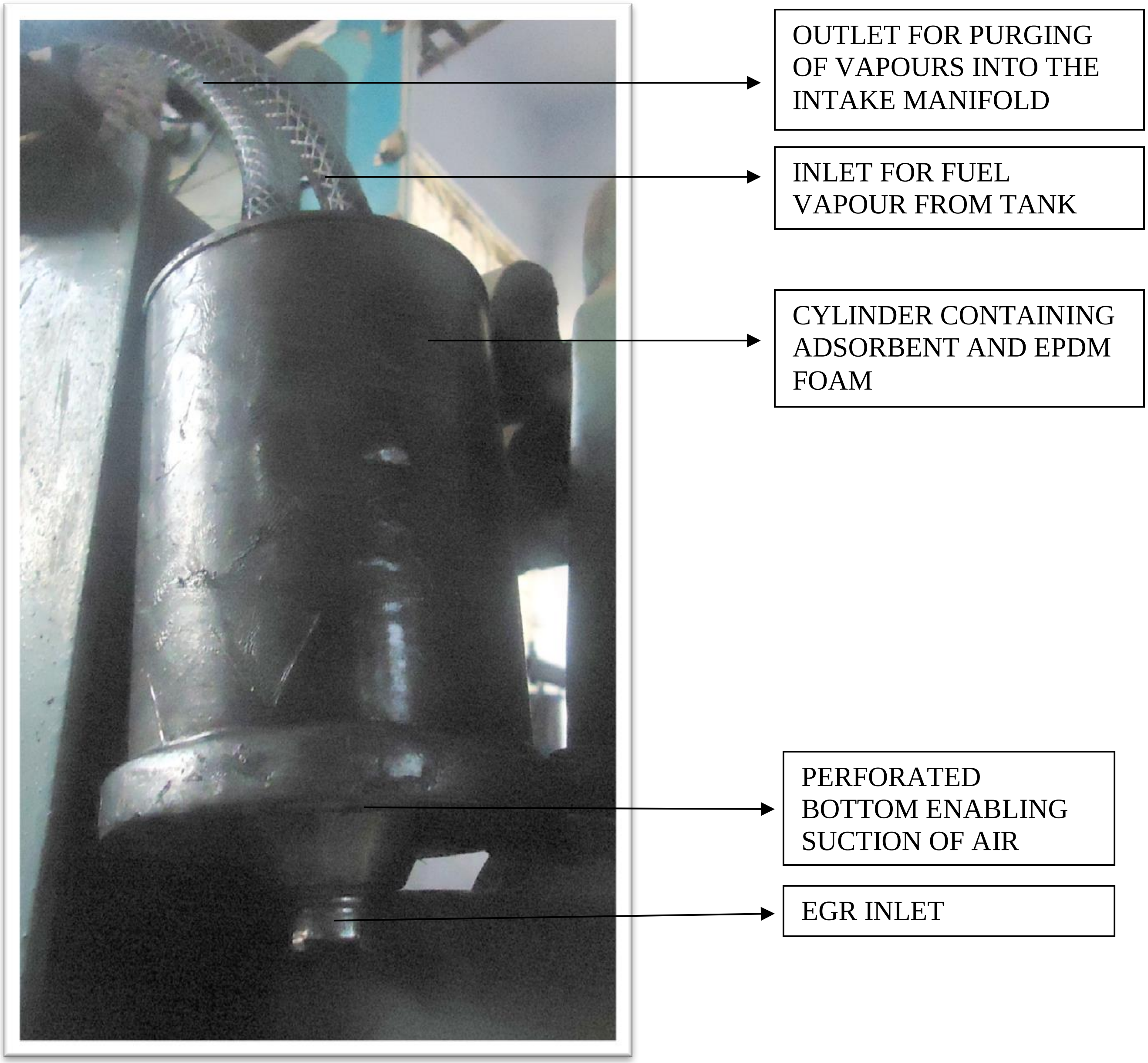


FIG. 7 FABRICATED CHARCOAL CANISTER

4.3.THE EXPERIMENT:

<u>4.3.1 Objective:</u> to study the adsorption and desorption efficiency of different adsorbent in a charcoal canister.

<u>4.3.2 Materials used:</u>

1. Fabricated Canister
2. Adsorbent

   I. Activated carbon
   II. Charred wood
3. Connecting tubes
4. A petrol engine
5. Intake manifold with a inlet for vapours from canister.
6. Weighing machine
7. Small beaker for sample collection

4.3.3Experimental Procedure:

1. The canister is filled with the adsorbent material and closed.
2. The canister is fitted to the tank outlet for adsorbing the vapours purging out of the tank.
3. Weight of empty beaker is measured (W_b).
4. Weight of beaker with fixed volume of adsorbent is measured (W_{ba}).
5. Weight of a fixed volume of sample of the adsorbent is taken at every hour interval in an electronic weighing machine (W_t).

FIG. 8

6. After complete saturation, the canister is fitted with the inlet manifold.

FIG. 9

7. The engine is started and the vapours purge into the engine cylinder due to suction pressure.

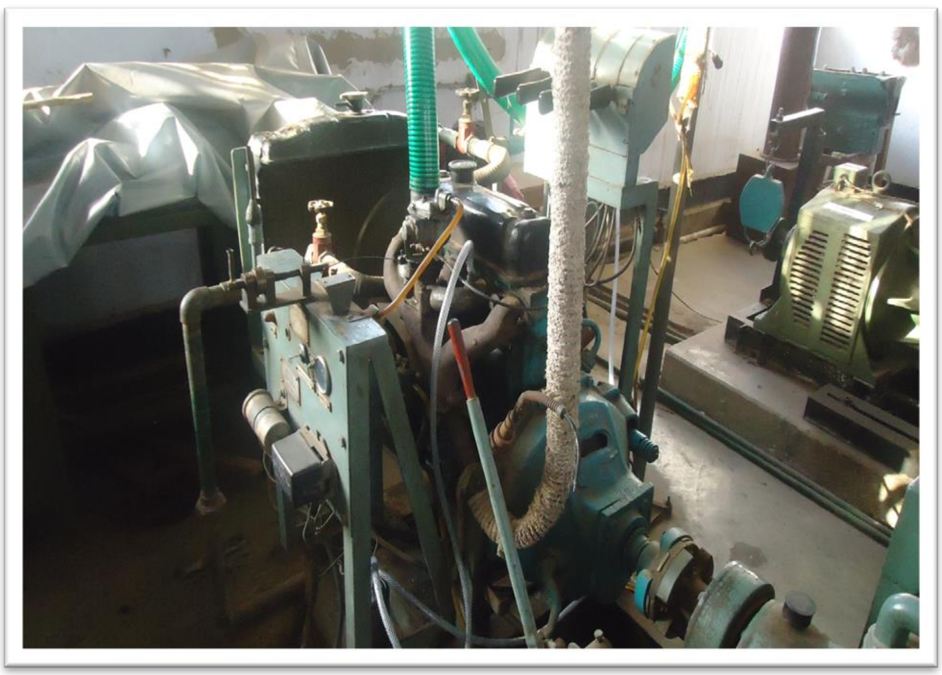


FIG. 10

8. Weight of the fixed volume of sample is taken in every fifteen minutes interval.
9. Weight of adsorbent(W_a)= W_{ba}- W_b
10. Weight of fuel adsorbed(W_f)= W_t - W_{ba}
11. Weight of fuel adsorbed/weight of adsorbent=W_f/W_a
12. This procedure is conducted for all the three adsorbent.
13. "mg of fuel/g of adsorbent vs. Time" graph is plotted for all the three adsorbent during adsorption as well as during desorption.

4.4 Observations:

Parametric conditions:

- Temperature constant(311k)
- Petrol volume constant(2 litre)
- During desorption load is constant(zero load)

4.4.1 ACTIVATED CARBON POWDER:

- Temperature: 311 K
- Weight of empty container(W_b): 11.073g
- Weight of container filled with activated carbon(W_{ba}): 19.077g
- Weight of activated carbon in the container(W_a): 8.004g

TABLE 4.1.1 Adsorption rate of activated carbon

SR NO.	***TIME***	***TOTAL WEIGHT OF THE CONTAINER*** W_t	***WEIGHT OF FUEL VAPOUR ADSORBED(mg)*** W_f	***mg OF FUEL VAPOUR/g OF ACTIVATED CARBON POWDER***
1	0	19.077	0	0
2	1	19.277	200	24.98
3	2	19.408	331	41.35
4	3	19.581	504	62.96
5	4	19.750	673	84.08

6	5	19.803	726	90.70

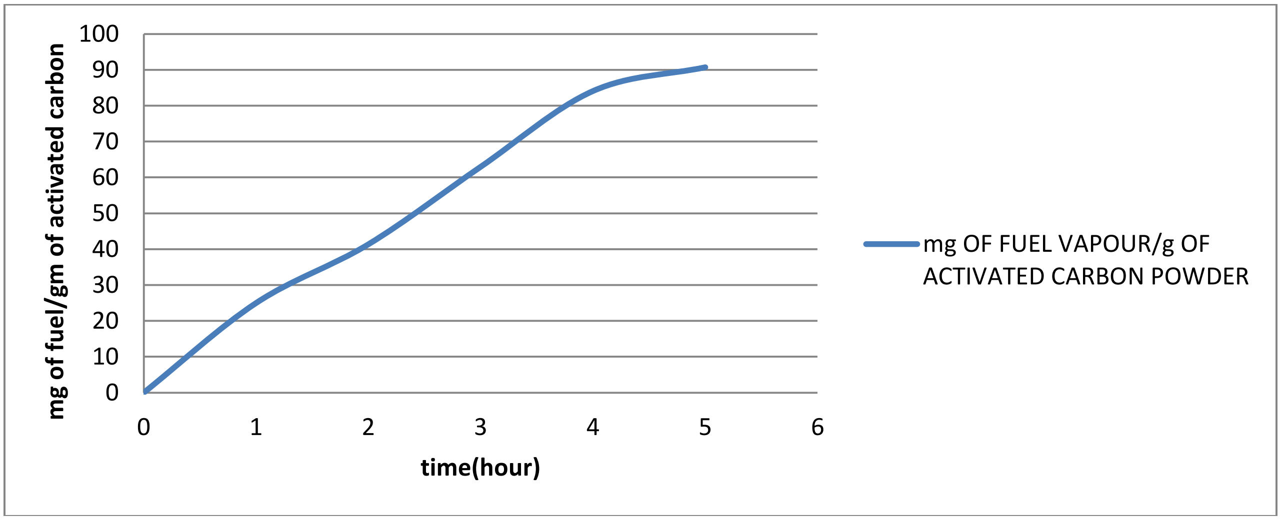


FIGURE 11 Adsorption rate of activated carbon

TABLE 4.1.2 Desorption rate of activated carbon

SR NO.	***TIME***	***TOTAL WEIGHT OF THE CONTAINER*** W_t	***WEIGHT OF FUEL VAPOUR DESORBED(mg)*** W_f	***mg OF FUEL VAPOUR/g OF ACTIVATED CARBON POWDER***
1	0	19.803	726	90.70
2	15	19.547	470	58.72
3	30	19.287	210	26.23
4	45	19.147	70	8.74

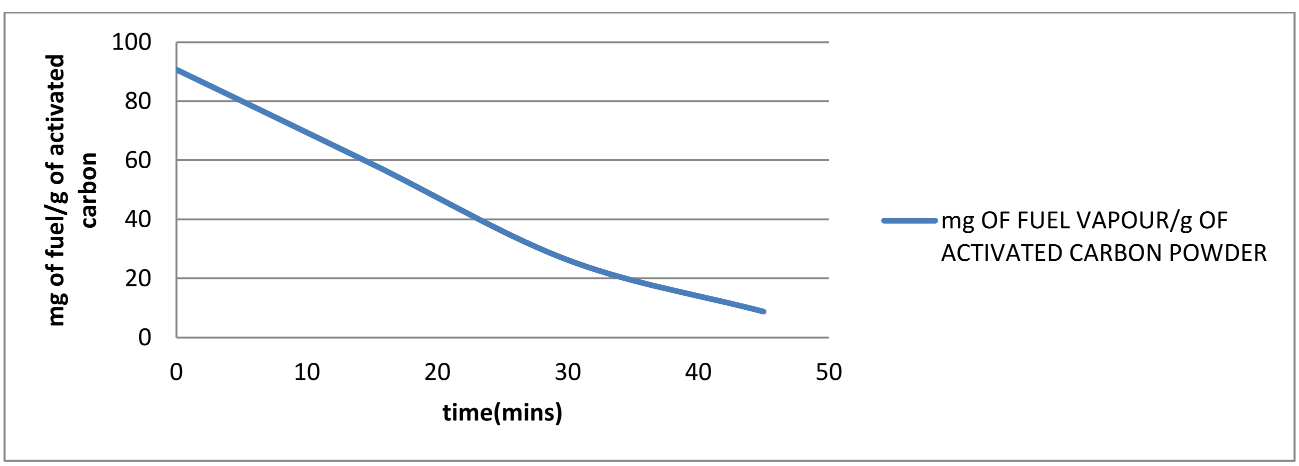


FIGURE 12 Desorption by activated carbon

4.4.2 CHARRED WOOD POWDER:

- Temperature: 311 K
- Weight of empty container(W_b): 11.073g
- Weight of container filled with charred wood(W_{ba}): 15.182g
- Weight of charred wood in the container(W_a): 4.109g

TABLE 4.2.1 Adsorption rate by charred wood

SR NO.	***TIME***	***TOTAL WEIGHT OF THE CONTAINER*** W_t	***WEIGHT OF FUEL VAPOUR ADSORBED(mg)*** W_f	***mg OF FUEL VAPOUR/g OF CHARRED WOOD POWDER***
1	0	15.182	0	0
2	1	15.267	85	16.63
3	2	15.334	152	29.75
4	3	15.401	219	42.86
5	4	15.442	260	50.89
6	5	15.480	298	58.32

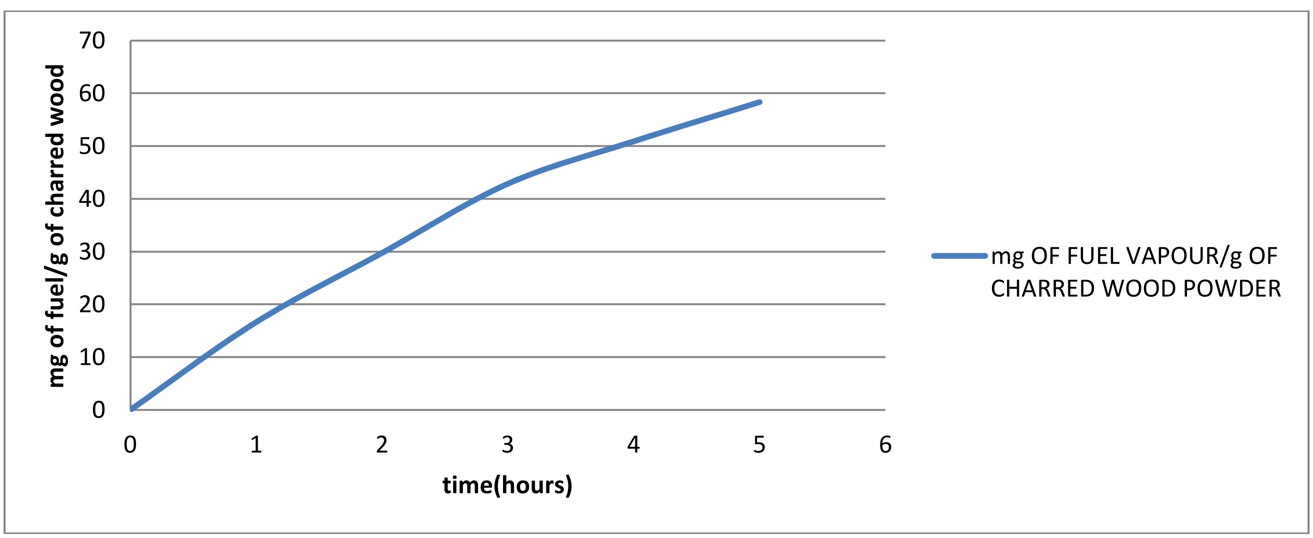


FIGURE 13 Adsorption by charred wood

TABLE 4.2.2 Desorption rate by charred wood

SR NO.	*TIME*	*TOTAL WEIGHT OF THE CONTAINER* W_t	*WEIGHT OF FUEL VAPOUR DESORBED(mg)* W_f	*mg OF FUEL VAPOUR/g OF CHARRRED WOOD POWDER*
1	0	15.442	298	58.32
2	15	15.309	127	24.85
3	30	15.248	66	12.91
4	45	15.201	19	3.71

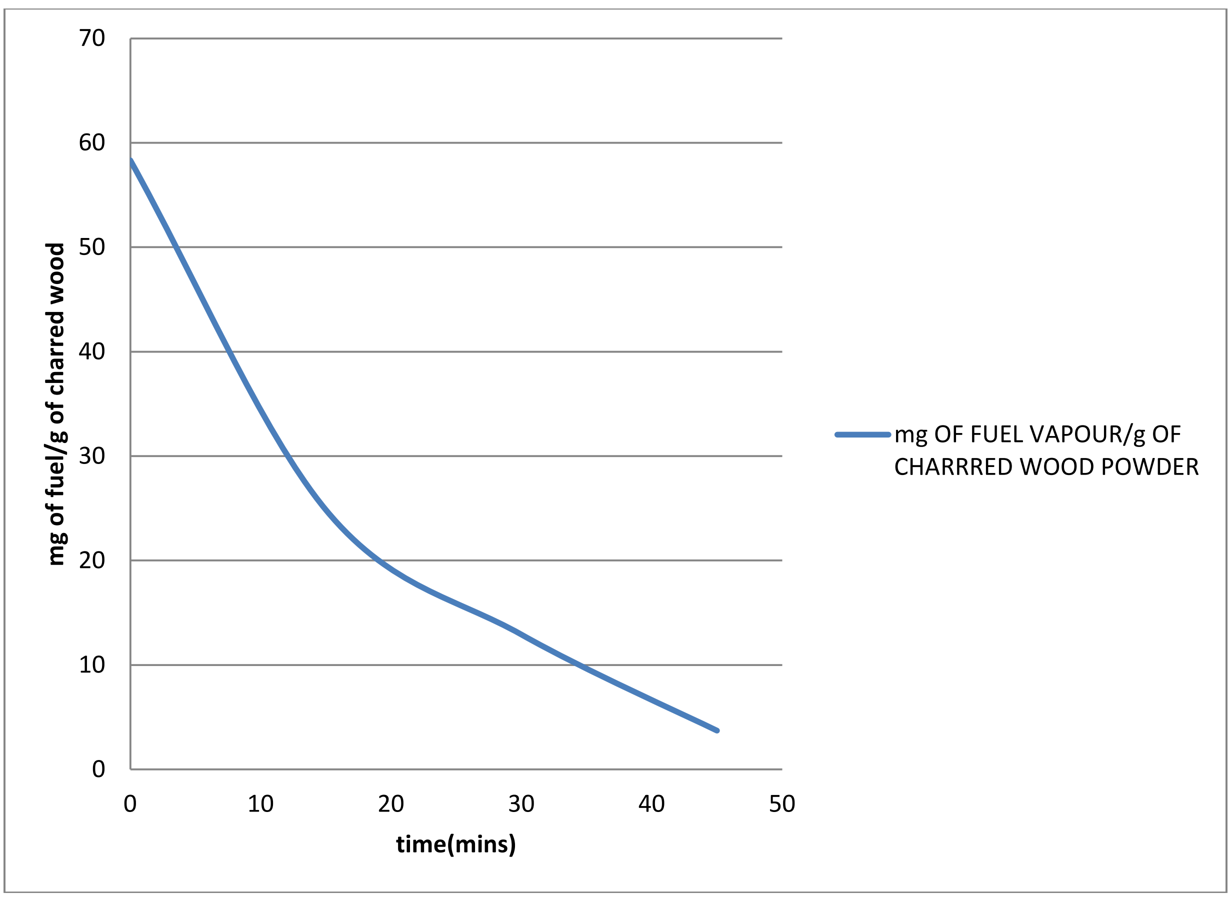


FIGURE 14 Desorption by charred wood

CHAPTER V

Results And Conclusion:

5.1 Adsorption by different powders:

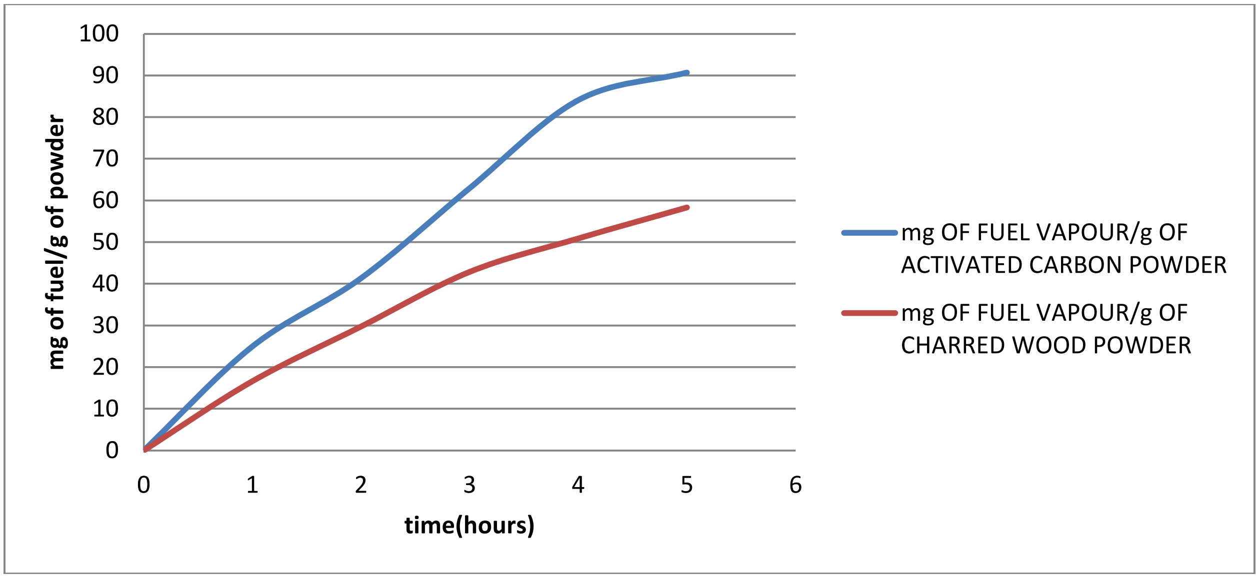


FIGURE 17 Comparative study of adsorption

Average Adsorption Rate:

- Activated carbon: 18.14(mg of fuel/g of powder)/hour
- Charred wood: 11.66(mg of fuel/g of powder)/hour

- *Efficiency:* Activated Carbon Powder> Charred Wood
- *Cost:* Activated Carbon> Charred Wood
- *Density:* Charred Wood>Activated Carbon
- The graph show that activated carbon is the best adsorbent followed by the charred wood powder.
- Charred wood has a decent adsorbing capacity and can be preferred for its very low cost, very low density and easy availability.
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5.2 Desorption by different powders:

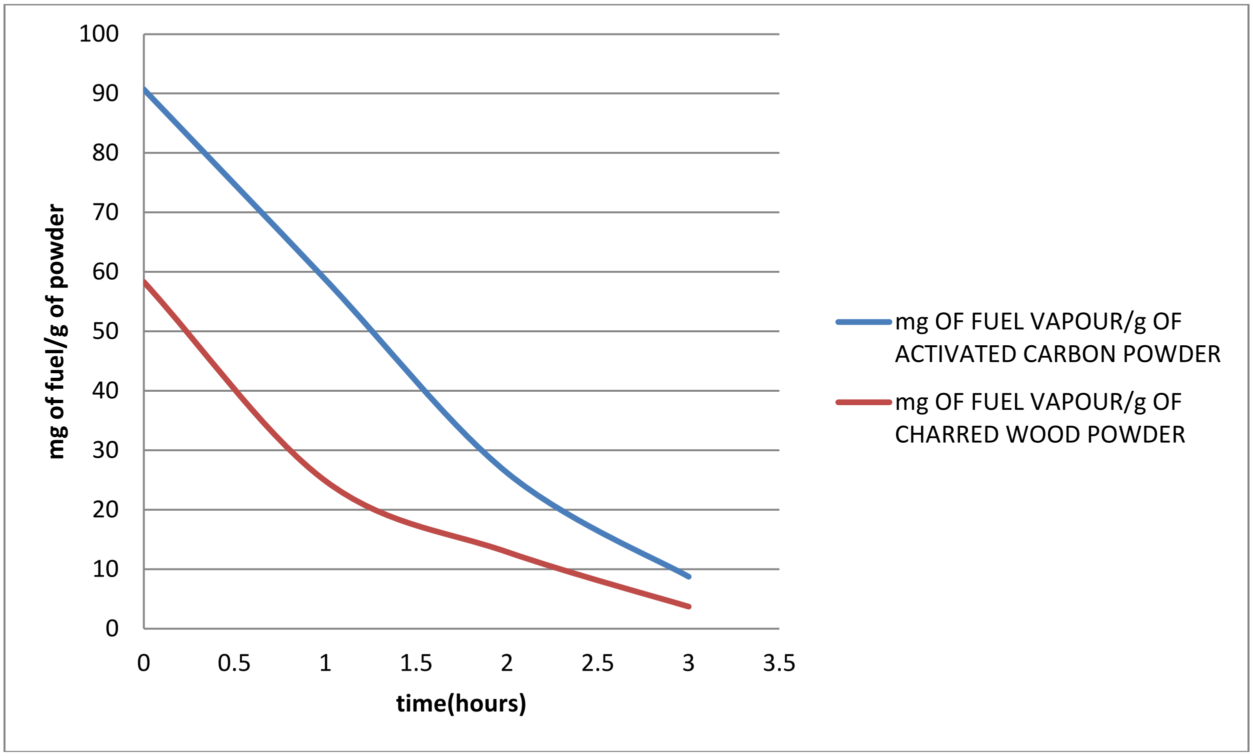

FIGURE 18 Comparative study of desorption

Average Desorption Rate:

- Activated carbon: 16.39(mg of fuel/g of powder)/hour
- Charred wood: 10.92(mg of fuel/g of powder)/hour

- Charred wood where as shows slower desorption which indicates the lower slope of desorption in the graph.
- Almost all the fuel are desorbed from the canister gradually when the engine is running.

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